Coastal Heritage

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Designing for Water

Strategies to Mitigate Flood Impacts

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Robin Smith, grounds manager at Medical University of South Carolina, clips greens in the campus' urban farm, which replaced a parking lot and was designed to retain water to mitigate flooding.

PHOTO/GRACE BEAHM ALFORD

Sea Grant | S.C. SEA GRANT CONSORTIUM
Coastal Science Serving South Carolina

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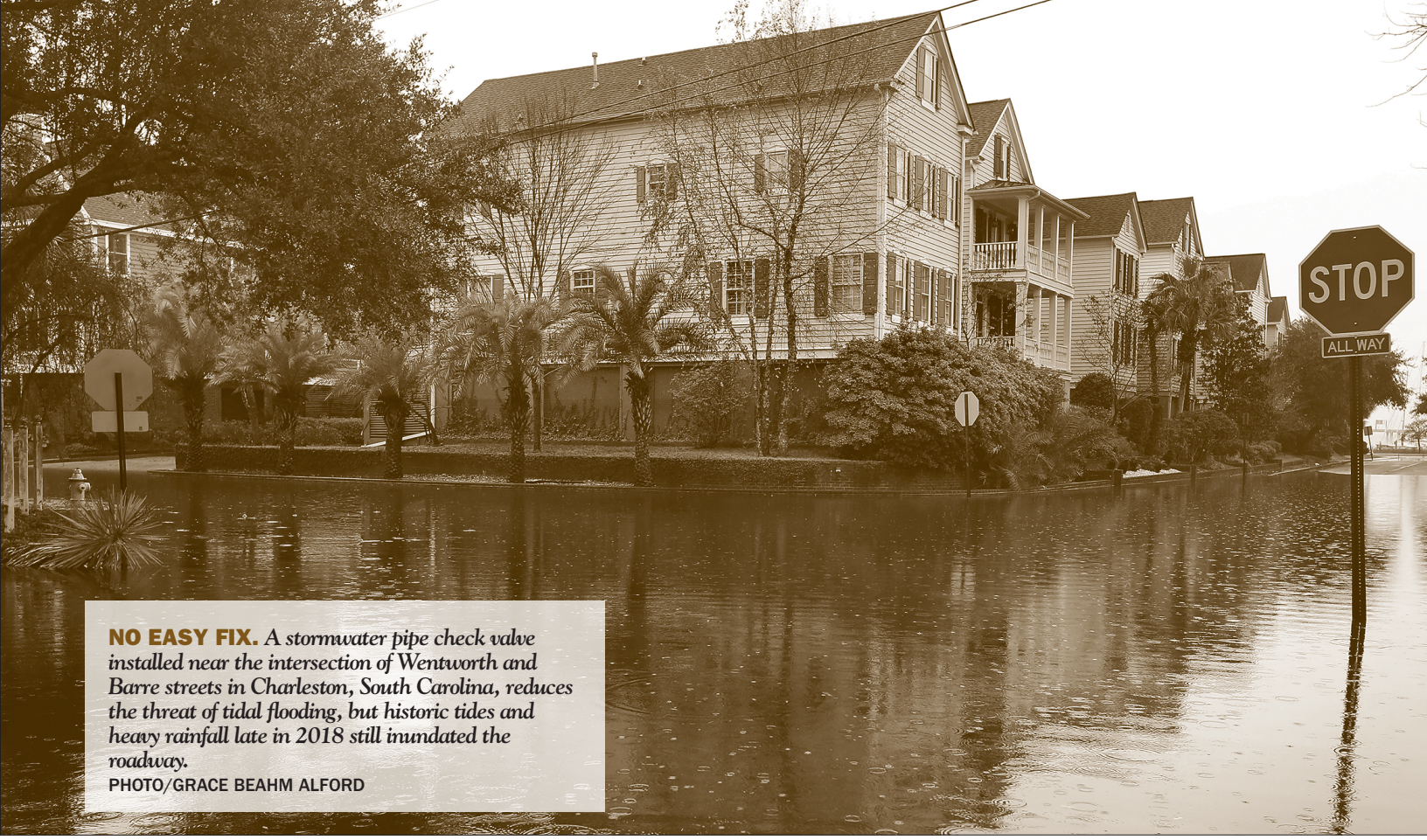


NO EASY FIX. *A stormwater pipe check valve installed near the intersection of Wentworth and Barre streets in Charleston, South Carolina, reduces the threat of tidal flooding, but historic tides and heavy rainfall late in 2018 still inundated the roadway.*
PHOTO/GRACE BEAHM ALFORD

Designing for Water

Strategies to Mitigate Flood Impacts

by Joey Holleman

On October 26, 2018, a full moon pushed the tide in Charleston, S.C., harbor to 7.37 feet. A year earlier, vehicles would have been sloshing through six inches of water at the intersection of Wentworth and Barre streets during such a high tide. But on this day, what neighborhood residents refer to as "Lake Wentworth," was a shallow puddle about two feet in circumference, a leftover from a light rain that fell overnight.

The tide was held at bay by a check valve on a stormwater pipe one block away under Beaufain Street. The pipe is part of a vast system designed to provide a path for rain falling on the Charleston peninsula to flow into the Ashley or Cooper rivers. Of course, water flows both ways, and extremely high tides push saltwater up those pipes and into streets.

The river outlets of some of the pipes for years were equipped with valves shaped like a duck's bill. Flexible rubber components came together when tides were high enough to put pressure on the two pieces of the bill. Unfortunately, the rubber on the duckbill valves lost elasticity when exposed to sunlight and saltwater. They never lasted long.

The valves wouldn't have been a major concern in the 1980s, when tidal flooding happened on average four times a year. But as sea levels have risen, and the peninsula has sunk slightly, the number of tidal flood days hit a record 38 in 2015. The record was broken with 50 in 2016, and the 46 tidal flood days in 2017 accentuated that this was the new norm. So the city decided to try new check valve technology with sturdier metal and plastic devices that slide deep and tight into pipes. They have just one flap, pushed closed by extreme tides flowing in from the river but remaining up if water is flowing from the streets.

The valves cost between $7,000 and $25,000, depending on pipe size, and installation expenses depend on size and location. By September 2018, the city had installed 22 check valves, at a cost of $755,000. Suddenly sunny day tidal flooding, also termed nuisance flooding, seemed to disappear at trouble spots like Wentworth and Barre.

The city of Charleston

MOVING WATER. *An extensive upgrade of Charleston's stormwater system features tunnels designed to convey large quantities of rainfall underground to the Ashley River.* PHOTO/CITY OF CHARLESTON

engineering department usually hears from residents only when they experience flooding. After check valves were installed, "we received some nice emails saying they didn't flood anymore," says Frank Newham, the city engineer in charge of the check valve project.

After several 7-foot-plus tides in early fall 2018 had little impact on the peninsula, Newham cautioned people not to get too excited about the check valves. They were just one tool for dealing with a complex problem. Then on November 23 and November 24, the components for an even more extreme tide came together – a full moon coincided with a weather system packing onshore winds and waves.

The tide gauge in Charleston harbor had risen above 8 feet only 21 times in the past century, according to National Oceanic and Atmospheric Administration (NOAA) records. On November 23, it hit 8.14 feet. With stronger wave action coming onshore on November 24, the tide hit 8.69 feet, the sixth highest on record. Tropical storm systems caused four of the five higher tides, and the other was a rare subtropical system on January 1, 1987.

"The check valves were working until water overtopped Morrison Drive, the Low Battery, and Lockwood Drive," Newham says. "Once that happened, the water sheet-flowed to low spots on the peninsula."

And Lake Wentworth was reborn, a metaphor on the challenges of engineering and designing to accommodate water. Compound flooding – arriving from the clouds and from storm surge – requires multiple defenses. Realizing this, the city purchased and installed pumps to redirect water that backs up in streets from heavy rains or severe tides, but it doesn't have enough to handle every problem spot during a widespread flood such as the one in late November.

WITH EXPERIENCE, DUTCH CAN LEAD THE WAY

Engineers say there are three ways to deal with flooding: Stop water from coming in, get out of the way of water, or accommodate water. Design solutions depend on geography, economy, and demand from residents.

Most major flood engineering projects worldwide fall in the stop-water category. The Thames Barrier in England utilizes rotating gates across the Thames River to keep extreme tidal surge from reaching London. The Three Gorges Dam project aims to tame the Yangtze River in China and protect riverfront communities downstream. And the Delta Works constructed in the Netherlands uses a variety of dams, dikes, and gates to block off major waterways from the North Sea.

In fact, flood control is a national obsession for the Dutch, 60 percent of whom live below sea level. Rather than try to keep water out, however, the Netherlands more recently has focused its flood efforts on getting out of the way and accommodating water – "Living With Water" is the theme. In Rotterdam, new parking garages are designed so bottom floors serve as reservoirs during heavy flooding. Urban landscapes are dotted with public spaces sunken below ground level, serving as parks during dry periods and stormwater overflow basins during flooding. Near the city of Nijmegen on the Waal River, a project called "Room for the River" converted an agricultural area back into a flood plain to reduce peak flood volumes.

As sea-level rise has begun to impact coastal communities around the world, flood engineering has become a Dutch export. After Hurricane Katrina's floods, New Orleans brought in engineers and planners from the Netherlands for a series of workshops dubbed Dutch Dialogues. Nearly a decade later, the efforts have prompted implementation of an Urban Water Plan, hiring of a

city chief resilience officer, and adoption of a comprehensive zoning ordinance that requires new development to detain and filter the first 1.5 inches of stormwater runoff.

A similar Dutch Dialogues effort in the Tidewater region of Virginia is in its early stages, and Charleston officials are in discussions about going through the process.

"As unique as Charleston is, you're not unique when it comes to floods," says Dale Morris, an American engineer who worked for the Dutch embassy and is one of the driving forces in the Dutch Dialogues. "The Dutch made 800 years of mistakes. You can learn from us."

Charleston's chief resilience officer, Mark Wilbert, sees value in having flood-planning mentors with so much experience.

"What struck me about the Netherlands was how much faith they put in the science community," Wilbert says. "They really put science front and center. It's science that gets you to the end game."

CURRENT SOLUTIONS MUST ADAPT FOR FUTURE SCENARIOS

Scientists say sea levels are rising. The fourth U.S. National Climate Assessment (NCA) released in November 2018 used the conservative estimate of 1 to 4 feet by 2100. With assistance from NOAA and S.C. Sea Grant Consortium, the city of Charleston in 2015 adopted a sea-level rise plan with guidelines based on 1.5 feet for non-critical infrastructure to 2.5 feet for critical infrastructure in the next 30 years.

The NCA also details increases in the number of extreme rainfall events and the amount of rain falling during those events. Powerful summer thunderstorms have long been common in coastal South Carolina. Extreme storms of the past decade have prompted the term "rain bombs." On July 20, 2018, a rain bomb dumped up to six inches in the Charleston area in six hours, creating traffic gridlock throughout the region.

Stormwater systems can be designed to handle rain bombs, but costs would be astronomical, says Newham, the city of Charleston engineer. The city is already spending approximately $200 million dollars on the new Spring/Fishburne stormwater system with multiple downshafts extending 120 to 140 feet below grade, where 12-foot diameter tunnels will transport stormwater to a pump station between the Ashley River bridges.

Street-level inlets that lead to downshafts are designed to handle the volume of 24-hour rainfall statistically given a 10 percent chance of falling in any year, sometimes referred to as a 10-year storm.

Should rain bomb frequency continue to grow, stormwater inlets might need to be adapted. Such adaptive capacity is being built into the city's other major flood-mitigation project – improvements to the Battery, a concrete wall that protects the tip of

HELP COMING. *In bad need of repair, the Low Battery at the tip of the Charleston peninsula is going to be raised and re-engineered to better protect against extreme tidal flooding and storm surge.*
PHOTO/JOEY HOLLEMAN/S.C. SEA GRANT CONSORTIUM

the peninsula.

When onshore wind and waves reach the harbor, extreme high tides can splash over the Battery now, especially a southern section known as the Low Battery that is several feet shorter than the rest. So in addition to shoring up the entire walls' support system, the city plans to raise the Low Battery by 2.5 feet, at an estimated cost of $60 million.

The new design includes more outlets to encourage rainwater – or the rare extreme storm surge that circumvents the wall – to flow quickly back into the river. The adaptive aspect of the design includes rails and posts atop the wall constructed to allow watertight panels to be slid into them before major events, or permanently as sea level rises, Newham says.

The neighborhood directly behind the Low Battery features 191 homes, some of them dating back centuries. Raising the wall offers a measure of protection for cultural touchstones. But like check valves, the Low Battery is just one piece of the puzzle.

HOSPITAL DISTRICT FACES LOCATION-BASED CHALLENGES

Few major entities in the Charleston area face more pressing flood issues than the Medical University of South Carolina (MUSC). Most of the campus was built on a former marsh and a mill pond filled to expand the peninsula west in the late 1800s and early 1900s.

The need to engineer for water around MUSC rose to critical levels after Hurricane Hugo in 1989. Hugo's storm surge rushed up to several feet high in hospital buildings and knocked out most of their electrical generators. Staff in the Intensive Care Unit had to use hand ventilators on patients who needed help breathing.

One solution post-Hugo was to move all generators and other critical equipment to higher floors. When Tropical Storm Irma in 2017 pushed up the highest storm surge since Hugo, MUSC's power supply remained safe, but other problems popped up.

Storm surge roared up to four feet deep on streets throughout campus. Lt. Bryan J. Wood, MUSC's emergency management coordinator, stood in chest-deep water at the campus' low point on Ehrhardt Street. "It was incredible," Wood says. "It really rushed in."

People were trying to drive through campus. Wood resorted to pulling bicycle racks into intersections to stop drivers. Hospital staff members wearing waders pushed a jon boat through streets to move physicians from one hospital building to another.

As surge remained high, the S.C. National Guard arrived with what looked like a troop-transport truck built for flood zones. Called a Light Medium Tactical Vehicle (LMTV), the truck was used to move personnel from building to building for the rest of the storm.

After Irma, MUSC purchased 40 road traffic barriers and its own LMTV from a law enforcement surplus program. "We want to be able to maintain self-sufficiency when it floods," Wood says. "It's an interesting dynamic with our location, but I think we're up to the challenge."

If maintaining operations during a flood is priority No. 1, reducing flooding on campus is priority 1-A. On this track, heavy rainfall is the focus. MUSC's low-lying campus is especially susceptible to rain bombs. Dozens of times each year, rain floods streets around and through the campus deep enough to grind traffic to a halt.

The campus is dotted with projects aimed at reducing flooding. In recent years, a large surface parking lot was

CREATING STORAGE. *Even the hard surfaces on the Medical University of South Carolina's urban farm are designed to retain water, with pervious pavers in the walkways and a cistern collecting rain from a shed's roof.*
PHOTO/GRACE BEAHM ALFORD

closed and converted into an urban farm that stores water which would have run off the parking lot into streets. Roofs of the two small equipment sheds on the urban farm are hooked to rain barrels and a cistern.

French drains, an engineered system that funnels water away from an area, also were installed, "but the entire garden is really one big French drain," says Robin Smith, MUSC's grounds manager.

The entrance to the adjacent Drug Discovery Building was designed with the first floor 12 feet above street level. Terraces leading to the building have a permeable gravel substrate and are filled with plants, including sweetgrass.

"We're trying to replant smarter, using plants that are more salt tolerant and suck up more water," Smith says.

IN THE WORKS. ***Long-range plans for the Charleston Medical District Greenway include trees, plants, and pervious pavement to replace what is now pavement painted green and trees in wooden containers.***
PHOTO/JOEY HOLLEMAN/S.C. SEA GRANT CONSORTIUM

The Charleston Medical District Greenway, the crown jewel of flood mitigation on campus, is a work in progress. To start the greenway, Doughty Street was closed to vehicular traffic from President to Ehrhardt streets in late 2017. Pavement was painted green, and the block was filled with large potted bald cypress trees and colorful chairs, tables, and umbrellas. Eventually, most of the pavement will be replaced by natural groundcover, the potted trees will be planted, and a vegetated wetland, known as a bioswale, will be created in a small adjacent parking lot.

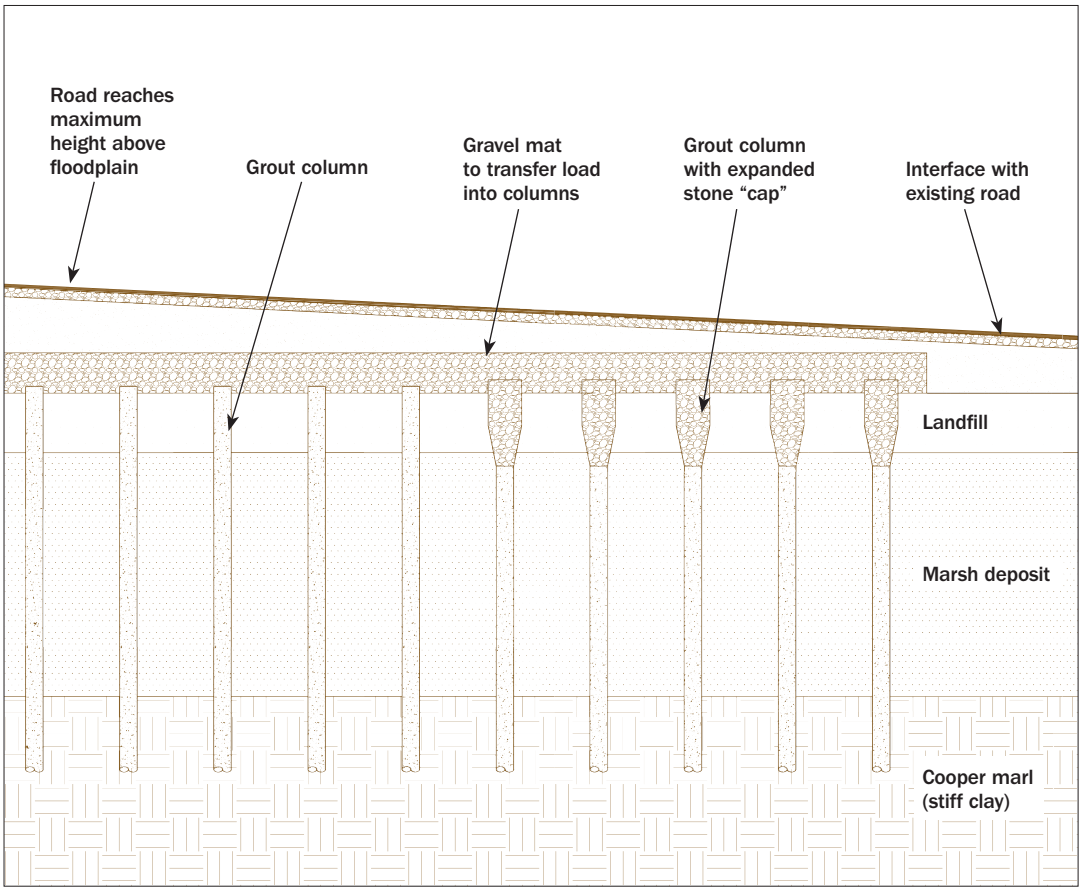
"It will not be just a green space – though that's a good thing – but also a form of flood resilience," says Dennis Frazier, MUSC's facilities and capital improvements administrator.

The long-range plan is to take over the next block of Doughty west to Courtenay Street. Fresh from a visit to the Netherlands with other Charleston leaders, Frazier sees potential flood projects he might not have dreamed about before. Could the greenway be built on top of underground garages, and could portions of those garages be designed to serve as giant cisterns during intense rain storms?

Such a project would be enormously expensive, but so are the prospects of recovering from flooding. MUSC determined Hurricane Matthew in 2016 caused about $600,000 in damages on campus, and Irma's tab was about $700,000. And those figures cover only damages to facilities, not the financial impact of moving patients and procedures to other facilities, or costs of employee overtime staffing.

"We're going to have to learn to collect water and hold it without contributing to other health concerns," Frazier says. "Each time we do an infrastructure project, we have to think about water."

The newest structure on the MUSC campus, the Shawn Jenkins Children's Hospital and Women's Pavilion, is being built with a ground level engineered to handle flooding up to 15 feet. Only once in the past century has tidal surge in Charleston Harbor topped 10.5 feet – when Hugo pushed up a 12.52-foot tide. And if flooding makes roads around the facility impassible, a heliopad on the roof is engineered to accommodate the U.S. Coast Guard's Jayhawk helicopter to evacuate patients or bring in supplies.



RISING ABOVE. *The specialized engineering of the main street through Charleston's WestEdge development raises the roadway higher than historic tidal flood levels.*
DIAGRAM/MENARD GROUP USA

NEW CONSTRUCTION CAN HIGHLIGHT FLOOD ENGINEERING

Just across Septima Clark Parkway from MUSC, the WestEdge development is rising, envisioned as a hub for residents, retail, and research. The city used the WestEdge site as a trash dump from 1952-1972, effectively creating land out of a former tidal wetland. Thus it's not surprising that extreme tides cause the most serious flooding in the neighborhood, says Michael Maher, the CEO of WestEdge Foundation. With that in mind, the new road network is being designed at a 10.5-foot base elevation.

WestEdge Street, the spine of the development, will be supported by a system devised by U.S. Wick Drain, a design-build geotechnical construction firm. A 16-inch auger drills holes 60 feet deep. The holes are filled with a concrete-like substance, creating what looks like stalactites in a grid, with one column every 6 to 8 feet.

The road gradually rises up from the existing street, and near the bottom of the slope, the columns include an expanded stone cushion or "cap" due to the close proximity to the pavement. A layer of compacted gravel connects the columns at the top, creating what resembles an upside down bed of nails. Another two-foot layer of gravel is spread across the bed of nails, then topped by up to six feet of fill that incorporates utility and stormwater pipes.

"Everything has to be out of flood level to be economically viable," Maher says. "In recent years, portions of (riverfront) Lockwood Drive have sunk at about three-quarters of an inch per year. We are making a long-term investment in this infrastructure, so we couldn't afford to create new streets that would sink."

RESTORING NATURAL FLOOD ENGINEERING

Marshes are nature's method of flood engineering, serving to slow, filter, and store stormwater along waterways. About 14 miles upstream from the WestEdge site, engineers are preparing to restore a marsh that had been converted into portions of a golf course half a century ago.

Open Space Institute (OSI), a land-conservation organization, often brokers deals between landowners interested in selling property and developers in need of property to offer as wetlands mitigation. The developers of WestEdge and the Palmetto Railways Naval Base Intermodal Facility on the former Charleston Naval Complex are working with OSI to restore a tidal marsh near Summerville as mitigation for wetlands impacted by their projects.

The former marsh was filled during construction of Kings Grant Golf Course in the 1960s, but fairways and greens of the closed course now sit unused. OSI purchased the low-lying portion of the course and will sell it to WestEdge and Palmetto Railways to serve as mitigation property. Engineers plan to punch breaks in berms along the river bank, allowing water to reclaim former wetlands.

The goal is to produce 58 acres of marsh bordered by swales and walking trails designed to absorb as much water as possible to help reduce flooding, says Patrick Moore, a project manager for OSI. It is much like the Dutch "Room for the River" project on a smaller scale, though it ranks as one of the largest marsh restoration efforts ever in South Carolina.

SHORELINES SOMETIMES NEED OUR HELP

Closer to the coast, marshes also reduce erosion of creek banks from waves and extreme tides. Sometimes, however, nature's engineering needs some assistance in the creation of living shorelines. One technique is to encourage the growth of oyster reefs, which facilitate the creation of marshes behind them.

The Nature Conservancy (TNC) is working with S.C. Department of Natural Resources (SCDNR) and S.C. Department of Health and Environmental Control (SCDHEC) to study how to best encourage natural growth of oyster reefs for living shorelines. SCDNR has been building oyster reefs on the edges of public land for years. The process has made researchers appreciate nature's engineering skills. Oysters only grow on hard surfaces, so solid substrate must be deployed. Oyster varieties that grow in South Carolina are intertidal, meaning they spend part of the day submerged and part of the day out of the water.

The research found it was critical to situate the right type of substrate in the right section of a creek, where it can serve as a toe end of a gently sloping shoreline. The reef must allow just enough sediment to wash over at high tide and settle behind at low tide. Sediment then slowly builds and marsh grass naturally, or with a little help from humans, takes root. Marshes grew behind TNC's test oyster reefs in research sites at Cape Romain, Winyah Bay, Wadmalaw Island, James Island County Park, and Mount Pleasant's Gold Bug Island.

"If we can replicate these types of projects on a larger scale, they can help," says Joy Brown, marine program manager for TNC in South Carolina. "It's important to keep that land and water connectivity instead of blocking it."

For now, living shoreline construction is rare, in part because a special permit is required. TNC, SCDNR, and SCDHEC are working to come up with a streamlined process for a general permit that could help bring down the expense for property owners. Costs for TNC's oyster-castle reef projects, including materials, engineered drawings, and surveys, ran up to $20,000 for a 100-foot reef. Brown says the goal is for living shorelines to cost the same or less than building a seawall, thus encouraging a natural flood engineering alternative.

NATURAL BULKHEAD. *In South Carolina tidal creeks, erosion associated with sea-level rise can be reduced by living shorelines, like this one built on Gold Bug Island in Mount Pleasant for a project determining best oyster-reef construction practices.*
PHOTO/GRACE BEAHM ALFORD

MEANS OF GETTING OUT OF THE WAY OF WATER CAN VARY

The most basic flood engineering consists of raising a structure on pilings, a defense used on South Carolina's barrier islands for generations. More homeowners are going to have to consider the option as sea levels rise. In communities participating in the National Flood Insurance Program (NFIP), homeowners in high flood-hazard areas who want to repair a substantially damaged home are required to raise the first floor structure above the community's base flood elevation. That often requires pilings.

The Buoyant Foundation Project (BFP) wants to give property owners a different choice – amphibious retrofits. A building's frame is jacked up temporarily, a subframe is built with connections to vertical guidance posts inserted into the ground beside the building, and a buoyant foundation is hung from the subframe. The building is then lowered onto supports connected to its original foundation.

The appearance of the structure changes little. When not in flood situations, the posts are inside outer sleeves sunk into the ground. During a flood, the building floats on its buoyant foundation, with the posts telescoping up from the outer sleeves like an old car antennae. The structure moves vertically, but the connection to the posts prevent it from moving horizontally. After the flood, the building slips back down and the posts telescope back into the sleeves in the ground.

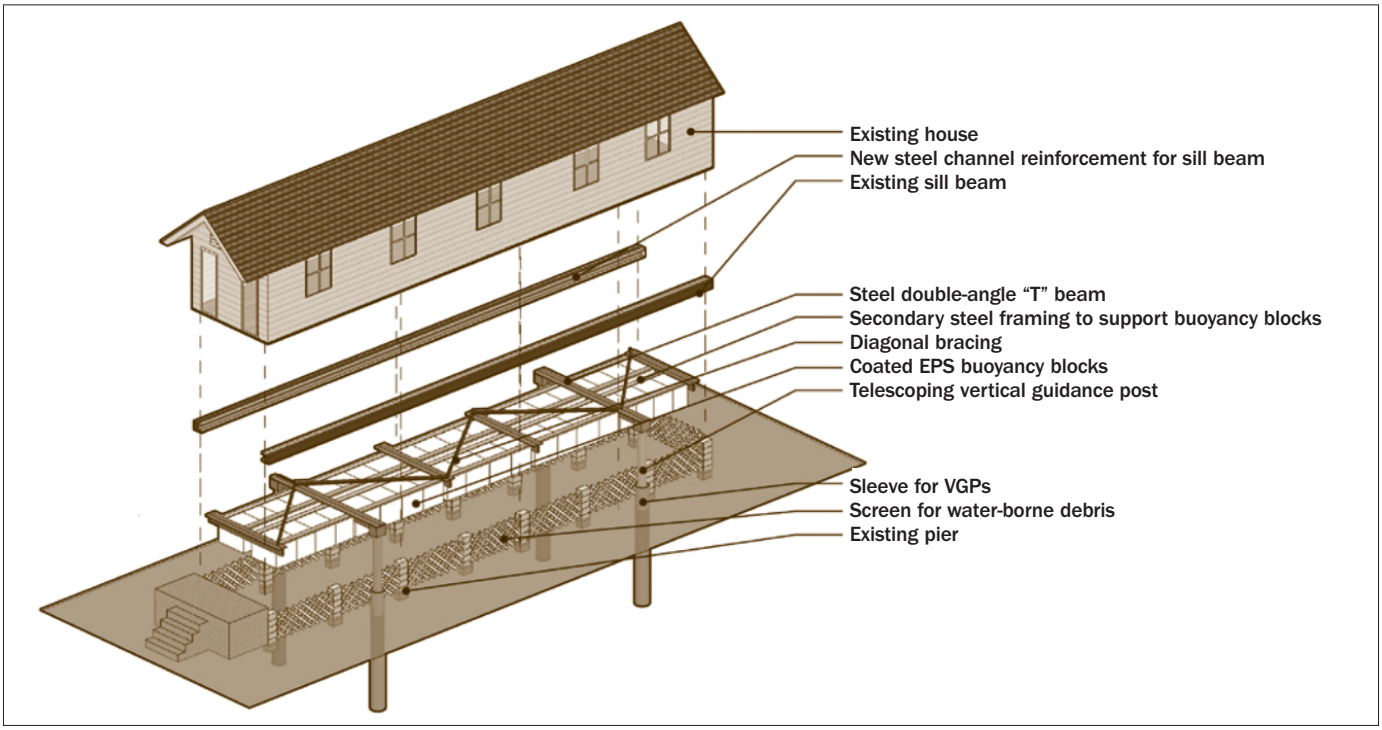
Elizabeth C. English, an associate professor in the School of Architecture at the University of Waterloo in Ontario, Canada and leader of the BFP team, says she started developing the concept while working at the Louisiana State University Hurricane Center. Well into the design process, she visited a flood-prone community where many homeowners had placed floats under houses and attached them to poles. "They had a seat-of-the-pants concept, and I learned a lot from them," English says. "My design complies with best engineering practices and features options to make it more attractive."

It's not a novel idea. New homes have been built attached to pilings in low-lying areas of the Netherlands, for example. But retrofitting existing homes to float because of increased flooding concerns is a new twist, English says.

Amphibious structures aren't suitable in areas where flood waters could have severe wave action or extremely high-velocity movement. BFP has installed amphibious foundations on four buildings in Vietnam, one in Louisiana, and one in Waterloo, Ontario, Canada.

"We're trying to build our proof of concept and show that it's easier and cheaper than elevating homes," English says. While the Federal Emergency Management Agency has approved the construction of amphibious retrofits, they don't yet qualify for NFIP policies.

For now, the ideal candidates for BFP are historical structures that would be demonstrably altered if elevated using standard methods. She has spoken with historic preservation groups in Charleston about possibly retrofitting a 19th century freedman's cottage.



ALTERNATIVE POSSIBILITY. *The Buoyant Foundation Project provides an option to elevating flood-prone buildings onto pilings, instead retrofitting buildings to float during flooding and drop back down on their foundations when waters recede.*
DIAGRAM/BUOYANT FOUNDATION PROJECT

WATER FLOW KEY TO REDUCING SUBURBAN RESIDENTIAL FLOODING

In Beaufort, S.C., the Mossy Oaks neighborhood offers an example of a dilemma popping up throughout the coastal region: Residential drainage basins need to be retrofitted to move water out more quickly. Portions of the 800-acre basin have flooded for decades, but the problem rose to crisis levels during Hurricane Matthew in 2016 and Tropical Storm Irma in 2017.

Leaders from the city of Beaufort, the town of Port Royal, Beaufort County, and the state formed a task force to examine the issue. A drainage study found nine pinch points, where water backed up in front of small culverts under roads on the way to Battery Creek. The water eventually also faced a major obstacle as it flowed through outlets in a former railroad embankment now topped by the Spanish Moss Trail, a popular recreation venue.

The heart of the suggested engineering remedy presented to residents in September 2018 would be to replace twin 36-inch culverts with twin 54-inch culverts at the pinch points. Portions of the trail embankment would be raised, making it the first line of defense against tidal flooding. Flap gates would be installed on twin 60-inch culverts in the trail embankment, designed to be shut in anticipation of extreme tides. A four-acre pond constructed in a park at the center of the neighborhood would be equipped to be pumped down ahead of extreme rains. The bill for the proposed changes is estimated at $5.3 million, which would be financed based on future revenue from residential stormwater fees, intergovernmental partners, and a federal grant.

The report built on data gathered for a citizens' task force on flooding put together by Beaufort Mayor Billy Keyserling with support from S.C. Sea Grant Consortium, University of South Carolina Beaufort, and the S.C. Small Business Chamber of Commerce.

"We might not be able to control sea-level rise at the local level, but we can understand the relationship between the intrusion of salt water and the drainage of fresh water," Keyserling says. "This is the first of several projects throughout the city where each will require a different solution to be addressed by the city over the coming years."

FLOODING IS PERSONAL, AND SO ARE SOLUTIONS

In the grand scheme of coastal

Retreating: The last resort

The most foolproof way to avoid flood damage is to retreat from the water, to give up on a location and move to higher ground. Attached to both home and place, few people opt to move inland or away from rivers.

The town of Newtok, Alaska, has appealed for federal funding to move its residents inland, and the Native American tribe living on Isle de Jean Charles in Louisiana is in the process of making a move to less flood-prone land.

In South Carolina, one candidate for retreat from flooding is the community of Nichols on the Lumber River in Marion County. The town of about 400 people suffered minor flooding for decades. Despite that history, nobody expected what has happened in the past three years.

Record-shattering rainfall throughout the region during Hurricane Matthew in 2016 swelled the river, and the town's small commercial district was under water for seven days. Just when the town was getting back on its feet, Hurricane Florence's rains swamped it for another five days in 2018. Nearly every structure and certainly every person in town has been impacted, says Sandee Rogers, town administrator.

After the 2016 flooding, the Federal Emergency Management Agency awarded the town $1.5 million through its Hazard Mitigation Grant Program to study the region's hydrology and better determine causes and potential solutions to flooding. Hydrologists were preparing to begin the study when Florence hit.

SMALL-TOWN DILEMMA. ***The rain-swollen Lumber River has inundated much of Nichols, South Carolina, twice in the past three years, prompting concerns about the future of the small town.***
PHOTO/TECH. SGT. JORGE INTRIAGO/U.S. AIR NATIONAL GUARD

"We think something has happened that's changed the water flow up the river," Rogers says. "The study will help determine the future of Nichols."

Many homes damaged by Hurricane Matthew had been repaired using private donations. None were raised substantially, Rogers says, because no previous flood had been as bad as Matthew. Many were flooded again by Florence. To qualify now for flood insurance payouts or federal assistance, most property owners will have to raise houses 4 to 5 feet, requiring expensive pilings they can't afford.

If the study finds no new underlying flood causes that have engineering remedies, "we'll have to regroup and face things we don't want to face," Rogers says.

flooding, building one section of living shoreline or installing a floating foundation under one historic house might be considered small in scale. In flood engineering and design, however, "a drop in the bucket" has real meaning. Massive projects like Charleston's stormwater tunnels are critical, but small changes also can add up to make a big difference.

Diane and Terence Bowers are believers. When they decided a few years back to move to higher ground in Mount Pleasant, they went all out on designing for water. Gutters on their new home drain into an underground cistern, a capture-and-storage concept dating back to ancient Rome. Many old Charleston homes were built with cisterns that are no longer used, in part for fear of mosquitos. The Bowers keep bugs at bay by dropping a mosquito-control ring in the cistern, while others use screens.

Water collected in the cistern is hooked to a drip system for watering plants and a lawn-sprinkler system. Overflow pipes connect to an underground dry-gravel well. The portion of the yard covered by grass has a sand substrate, and most other surfaces are either pervious pavers or gravel. They added an art studio in the back that isn't hooked into the cistern, but it has a vegetated green roof and a rain barrel, and water that ends up in the rain barrel will be used to irrigate raised garden containers.

Their property is on a high ridge in the Old Village neighborhood, 23 feet above sea level. The underlying soil is sandy. Using standard construction, their house would have been extremely unlikely to flood, but water flowing from it might have contributed to flooding a few blocks away.

"Runoff is not a good thing," Diane Bowers says. "It pollutes, and it floods houses. We're trying to be good stewards of the land."

The Bowers have created what could be a poster yard for low-impact development (LID). Joshua Robinson of Charleston-based Robinson Design Engineers refers to such small LID projects as the low-hanging fruit of flood engineering and design.

Robinson wonders if Charleston might have been better off siphoning a few million dollars from its tunnel-and-pump-station projects and using the funds to incentivize property owners to install green roofs. An 18-inch soil profile with plants on a roof can strain a building's structure, but properly designed green roofs also reduce stress on stormwater systems. Even a 4-inch soil profile can store over an inch of rainfall.

S.C. Sea Grant Consortium-funded research by Nigel Kaye, an associate professor of civil engineering at Clemson University, studied the efficiency of green-roof designs. Kaye found that water passes relatively quickly through modular containers with only soil and plant material, thus they fail to detain significant volumes of rainfall. However, a rooftop system with a second layer of empty containers installed beneath the soil-and-plant modules can hold water and release it through small openings. That type of system reduced peak storm runoff by 88 percent compared to a standard impervious roof.

Charleston, with its many historical structures, faces green-roof

REPURPOSING WATER. *Diane and Terence Bowers' house in Mount Pleasant features downspouts connected to an underground cistern, where stored water is used to irrigate the lawn and plants.*
PHOTO/GRACE BEAHM ALFORD

installation challenges. Still, green roofs are popping up – on the Veterans Administration hospital, Trident Technical College's nursing school, the Taco Boy restaurant on Huger Street, and Mount Pleasant's Town Hall.

Flyway installed a green roof on its building at 1630 Meeting Street in Charleston and has been happy with the results, says company president Lindsay Nevin. The plants have held up well with minimal maintenance. In addition to reducing runoff, plants provide a nice aesthetic from porches overlooking the roof and serve as insulation, Nevin says.

Of course, green roofs are just one tool in a design toolbox. One of Robinson's more audacious dreams is to use stormwater fees already paid by property owners to buy enough 1,000-gallon cistern tanks to fill a warehouse. To jump-start the effort, they could be offered for free to contractors doing new construction or anyone interested in revamping the way water runs off their roof.

FINDING SOLUTIONS. *A small art studio at the back of the Bowers' yard isn't attached to the cistern, but rainfall runoff was reduced by the installation of a green roof (darker than the lawn in this image) on the studio.*
PHOTO/GRACE BEAHM ALFORD

"Engineers are expected to have a silver bullet that involves machinery and millions of dollars," Robinson says. "But it's a problem of perception, and it requires communications more than engineering. Each person who owns land is part of the solution. They need to realize that flooding is like heavy traffic. You have to realize you're not in traffic, you are the traffic."

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NEWS & NOTES

Cannizzo, Lundsted, and Weinstock earn fellowships

S.C. Sea Grant Consortium nominees Zachary Cannizzo, Justine Lundsted, and Stacey Weinstock have been selected for the 2019 Dean John A. Knauss Marine Policy Fellowship, providing them the opportunity to spend a year living, working, and learning in the Washington, D.C. area.

The competitive fellowships are offered by the National Oceanic and Atmospheric Administration's National Sea Grant College Program. Recipients are matched with host organizations in the legislative and executive branches of government.

Zachary Cannizzo
PHOTO/LINDA CANNIZZO

Cannizzo earned a bachelor's degree in biology and biological aspects of conservation from the University of Wisconsin-Madison and recently completed his Ph.D. in marine science at the University of South Carolina. His research work focused on climate-mediated range expansion of the mangrove tree crab *Aratus pisonii* into the salt marshes of northern Florida and southern Georgia.

During his fellowship year, Cannizzo will work in the Marine Protected Area Center of NOAA's Office of National Marine Sanctuaries. His role will be to support collaborative interagency efforts related to climate vulnerability and adaptation of Marine Protected Areas and the protected species found within them.

Justine Lundsted
PHOTO/PROVIDED BY JUSTINE LUNDSTED

Lundsted obtained her bachelor's in marine science at Coastal Carolina University before entering a joint Peace Corps Master's International and M.S. in Environmental Studies program at the College of Charleston. On the way to earning her master's degree, she spent 26 months in the Philippines, where she worked as a coastal resource management advisor with a local government evaluating Marine Protected Area effectiveness, conducting socio-economic assessments, and assessing coastal ecosystem health.

Lundsted's Knauss fellowship will be a joint coastal resource management position between the Environmental Protection Agency and the nonprofit Coastal States Organization.

Stacey Weinstock
PHOTO/PROVIDED BY STACEY WEINSTOCK

Weinstock has two B.S. degrees from Virginia Tech – one in fisheries science with a focus on marine fisheries and one in wildlife science with a minor in biology. She worked as a graduate research assistant in the S.C. Sea Grant office while earning her M.S. in Environmental Studies from College of Charleston.

Weinstock's thesis work concerned trip satisfaction among recreational charter fishing stakeholders. She will continue in that field during her Knauss year as an international policy fellow in the Office of Law Enforcement at NOAA with a focus on illegal, unreported, and unregulated fishing.

Davis and Knapp join Consortium staff

The S.C. Sea Grant Consortium has two new staff members – Human Resources Manager Marlena Davis and Coastal Resilience Specialist Landon Knapp.

Marlena Davis
PHOTO/SUSAN FERRIS HILL/S.C. SEA GRANT CONSORTIUM

Davis has 15 years of experience in the human resources field in the health care, education, and hospitality industries. She also has worked as an airline customer service representative and as a music teacher in schools.

Davis grew up in Charleston and earned a bachelor's degree in music at Furman University. She provides music instruction, specifically in strings, for youngsters and adults at Charleston's Emanuel African Methodist Episcopal Church, where she is active in the women's ministry and leads the Praise Dance team.

Landon Knapp
PHOTO/SUSAN FERRIS HILL/S.C. SEA GRANT CONSORTIUM

Knapp has more than 10 years of experience in coastal environmental science and management, including time with a nonprofit, in a biological laboratory, and doing research work with the National Oceanic and Atmospheric Administration. Most recently, he was

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a project manager with the S.C. Department of Health and Environmental Control's Office of Ocean and Coastal Resource Management.

Knapp earned a B.S. from Old Dominion University in Virginia and both Master of Public Administration and M.S. in Environmental Studies degrees from the College of Charleston. His thesis work focused on analyzing the relationships between environmental quality, biodiversity, and stakeholder value for a National Estuarine Research Reserve site. In his new role, Knapp will provide hands-on operational and technical support to coastal communities, resource managers, and interest groups to foster coastal community resilience.

S.C. Environmental Awareness Award goes to educator

Sean Poppy, an outreach educator at the Savannah River Ecology Laboratory (SREL), is the latest winner of the S.C. Environmental Awareness Award.

In his nearly 20 years with the U.S. Department of Energy facility, Poppy has presented live animal shows that introduced hundreds of thousands of children to the ecological diversity found on the 200,000-acre Savannah River Site. The hands-on presentations have become so popular that schools and youth groups have to book them months in advance. In addition to the animal shows, Poppy conducts wildlife safety talks and manages the SREL Conference and Education Center and its animal care complex.

The Savannah River Site is home to dozens of species of reptiles and amphibians. One of the stars of Poppy's shows is Scooter, a wild coyote Poppy rescued. Scooter helps educate the public about the impacts of invasive species.

"When you think about snakes, alligators, toads, frogs, turtles, and even coyotes, they are not always considered the animal candidates that the public eagerly embraces," wrote one of Poppy's co-workers in nominating him for the award. "However, when you see children and adults open their eyes, hearts, minds, and arms to these creatures, you really understand how special an environmental educator Sean Poppy is."

The annual award, established in 1992 by the S.C. General Assembly, recognizes outstanding contributions toward protection, conservation, and improvement of South Carolina's natural resources. Poppy was presented with the award at an event at the S.C. Department of Health and Environmental Control (SCDHEC) headquarters in Columbia on November 27, 2018.

Members of a committee made up of representatives from SCDHEC, S.C. Forestry Commission, S.C. Department of Natural Resources, and S.C. Sea Grant Consortium select the award winner from nominations submitted by the public.

For more information on the S.C. Environmental Awareness Award and for details on how to nominate someone for the 2018 honor, go to www.scseagrant.org/Content/?cid=1039.

Sean Poppy, the 2016 S.C. Environmental Awareness Award winner, uses native animals to introduce school children to the wonders of nature. Scooter the coyote was malnourished and dehydrated when found near a school in Jackson, South Carolina. He recovered and now serves as an education animal.
PHOTO/SEAN POPPY/SAVANNAH RIVER ECOLOGY LABORATORY

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Citizen Science Association Conference

Raleigh, North Carolina
March 13-17, 2019

The conference highlights the important role of citizen science projects, and their challenges. The main tracks deal with collecting data, using the data to improve human and environmental health, and the role of the education community in citizen science. Visit www.citizenscience.org/association/conferences/citsci2019 for more information.

South Carolina Hazard Mitigation Conference

Hilton Head, South Carolina
March 18-20, 2019

The S.C. Association for Hazard Mitigation brings together professionals in engineering, planning, government, private business, and academia to learn about the latest research on managing the problems associated with disasters. Topics covered include floodplain mapping, low impact development, and mitigation grants. For more information, visit www.scahm.org.

Sea-Level Hotspots Workshop

Norfolk, Virginia
April 23-25, 2019

The workshop will bring together the scientific community, decision-makers, and coastal stakeholders to discuss the key drivers of sea-level change and identify resources and efforts aimed at increasing adaptation and resilience in coastal communities from Florida to Maine. Visit www.usclivar.org/meetings/sea-level-hotspots-florida-maine for more information.

Subscriptions are free upon request by contacting: Joey.Holleman@scseagrant.org

ATTENTION SCHOOL TEACHERS! The S.C. Sea Grant Consortium has designed supplemental classroom resources for this and past issues of *Coastal Heritage* magazine. *Coastal Heritage Curriculum Connection*, written for K-12 educators and their students, is aligned with the South Carolina state standards for the appropriate grade levels. Includes standards-based inquiry questions to lead students through explorations of the topic discussed. *Curriculum Connection* is available online at www.scseagrant.org/education.

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